Title: **Exploring Newton's 2nd Law with Computer Aided Data Collection and Analysis**

Brief Overview:

With the increasing availability of computers in the classroom it is possible to collect data with precision and ease unheard of in decades past. This unit consists of a lab in which students test Newton's 2nd law using Pasco Smart Pulley hardware and Vernier Logger Pro software on Macintosh computers. If you have the hardware, it is possible to go an extra step and have the students submit their work electronically across a network to your teacher station. A dream today perhaps, but increasingly likely, as we enter the 21st century.

Links to NCTM 2000 Standards:

- **Mathematics as Problem Solving**
  The students will apply a mathematical model to the description of a real-world system.

- **Mathematics as Connections**
  The students will see the connections between mathematics and other disciplines.

- **Algebra**
  The students will use tables and graphs as tools to interpret an equation.

Links to National Science Education Standards:

- **Unifying Concepts and Processes**
  The students will use balances to determine the mass of their Hall's Carriage. They will measure distance and time and plot graphs relating the two.

- **Science as Inquiry**
  The students will perform an experiment to confirm the predictions of a mathematical model.

- **Physical Science**
  The students will develop a better understanding of how forces cause changes in motions and will apply $F = ma$.

- **Science and Technology**
  The students will apply technology to assist them in collecting data, preparing graphs, and performing calculations of slope.

- **History and Nature of Science**
  The students will understand that Newton's Second Law of Motion is an accepted scientific explanation because it agrees with experimental and observable evidence.

Links to Maryland High School Science Core Learning Goals:

- **Skills and Processes**
  The students will attempt to affirm the validity of Newton's Second Law of Motion by collecting data and comparing the results of the experiment to the predictions of theory.

  The students will use balances, photo gate timers, and computer graphing to collect and analyze the data (Goal 1, Expectation 3, Indicator 3 & Expectation 5, Indicator 4) and suggest sources of error in the experiment. (Goal 1, Expectation 4, Indicator 7)

- **Concepts of Physics**
  The students will observe the acceleration of a cart and compare the observation to predictions utilizing Newton's Second Law. (Goal 5, Expectation 1, Indicator 3)

Grade/Level:

Physics, Grades 11 - 12

Duration/Length:

2 - 3 class periods

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- Determining mass with a triple beam balance
- Basic operation of the computers (Mac or PC versions of the software are available.)

Student Outcomes:

Students will:

- measure the acceleration of an object pushed by a known force using computer aided data collection.
- compare the experimental result to predictions using Newton's Second Law of Motion.

Materials/Resources/Printed Materials:

- Motion carts of some kind (e.g., Hall's carriages for this activity, but it can be performed with many kinds of carts from wooden skate style to air tracks and elaborate low friction wheeled tracks, such as the Pasco dynamics carts and track. What is important is that you adjust for minimum friction and encourage the students to avoid combinations with too much mass on the cart and too little mass pulling.)
- Pasco Smart Pulleys and hardware to link to the computer. (e.g., the ULI interface from Vernier Software. They are rather costly at $299, but they are extremely versatile. As you acquire computers, it is good to encourage your school to buy enough ULIs to go with the computers in the science rooms.)
- Logger Pro software from Vernier Software. At $59.00 for an unlimited site license, this is one of the few true bargains out there. If you are unfamiliar with Dave Vernier's programs, you are in for a treat.)

Development/Procedures:

The worksheet provides instructions for verifying Newton's Second Law of Motion. Gather the materials together before the class and prepare a supply of worksheets. Give the worksheets out and let the students read through the procedure. Model briefly the equipment setup, then let the students work through the experiment.

At the conclusion of the experiment, ask the students to comment in writing on their results. Encourage this exercise in written expression. Grade conclusions as much as for how the results are explained as for what the results were. Be a stickler for clarity, good grammar, and good spelling.

This activity is a rather straightforward test of Newton's Second Law of Motion. The main intent is to encourage any teachers who have not tried computer data collection to take the plunge. Get the stuff and try it for yourself. After you have done so, you can demonstrate the procedure to the students. They will take off from there!

Assessment:

During the lab activity, circulate among the students. Look at each group's first trial. Have them explain to you what the data means. Check over their calculations for neatness and accuracy. Encourage both. If all looks well, let them proceed unhindered.

After the activity is completed, collect each group's work. Award points for each completed test and for the quality of the summation paragraph(s).

Possible rubric: 1 point each completed trial
1-5 points for summation
1 point for each question posed in the directions that are answered.
Fifth point if the reasons offered for the error are reasonable

Extension/Follow Up:

Have the students attempt to demonstrate some of the relationships implicit in Newton's Second Law. For example, if they keep the total mass constant but change the hanging mass, "does doubling the hanging mass double the acceleration?" or "does tripling the hanging mass triple the acceleration and so on?".

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Sources Mentioned Above:

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Exploring Newton's Second Law

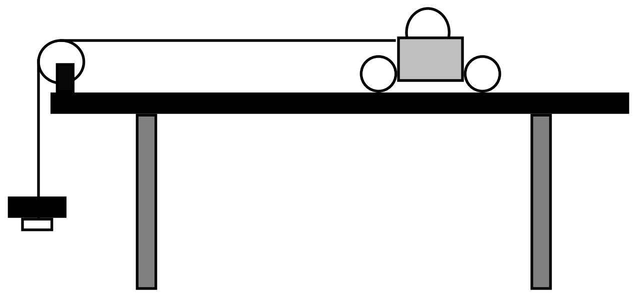
Background: You know that the harder you shove something, the faster it goes. You also know that it's easier to push an empty grocery cart than a full one. Newton's Second Law of Motion ($F = ma$) implies all that, but does it really work?

Objectives:

1. Measure the acceleration of an object pushed by a known force using computer aided data collection.
2. Compare the experimental result to predictions using Newton's Second Law of Motion.

Equipment:

Hall's Carriage	String
Mass set and hanger	Pasco Smart Pulley
Logger Pro software	Computer



Procedure:

1. Set up the equipment as illustrated.
2. Load the software and prepare to collect data as shown by your instructor. You will want to generate a graph of speed vs. time. The slope of this graph will give you acceleration. Because of the way in which Logger Pro handles data, a graph of acceleration vs. time is much less useful.
3. Place a moderate amount of mass in the cart (perhaps .2 kg) and a similar amount on the hanger. Allow the cart to accelerate across the desk and record the data.
4. On the graph, select the regression line and have the computer calculate slope for you. This is the acceleration for your trial. Print the graph and write all mass information on it. Be sure to include the mass of the cart, the masses in the cart, and the mass of the hanging mass and hanger.
5. Repeat this 6 to 10 times, changing the masses each time. Try to get a range of data from heavy carts pulled by moderate masses to light carts pulled by heavy masses.

Analysis: Do these for each trial on the printout.

1. Calculate the weight of the hanging mass and hanger.
2. Using $a = F/m$, calculate the theoretical acceleration for each trial.
   Note: m in this case is the total mass of the entire accelerated system.
3. Calculate the percent error. $\%\text{error} = \dfrac{|T - E|}{T} \times 100$

Conclusion: Write a paragraph(s) in which you comment on your results. Does $F = ma$ seem to work? Did your experimental acceleration match your theoretical values? Is error higher for larger hanging masses or lower, or is there no obvious pattern? What do you think are the sources of error in this experiment?